

SUSTAINABILITY AND LANDFILL SITE ALLOCATION BY USING GIS: A CASE STUDY FROM RAMALLAH, PALESTINE

MAHAMID, I.¹ & THAWABA, S.²

¹Department of Civil Engineering, Birzeit University, Ramallah, West Bank

²Department of Architectural Engineering, Birzeit University, Ramallah, West Bank

Corresponding author: Dr. Salem Thawaba,

Department of Architectural Engineering, Birzeit University, Ramallah, West Bank

ABSTRACT:

Shortage of land for waste disposal and inappropriate landfill site is one of the biggest problems in most of large urban areas. Therefore more efforts needed to overcome this problem. A suitable landfill site should be selected carefully by considering regulations and constraints issued by different environmental agencies or local authorities such as environmental affairs departments. In this research ,a potential site for an appropriate landfill area for Ramallah Governorate was determined by using geographic information system (GIS) as a tool to aid the decision making process. To achieve this purpose, thematic layers and different tabular data such as topography, land use, roads network, ground and surface water, infrastructure, and urban areas were collected from different institutions and governmental agencies in Palestine. Data were used to create the vulnerability map for the area and buffer zones in order to find out the best location for the anticipated regional landfill site.

Keywords: Landfill, GIS, solid waste, Palestine, vulnerability, municipal waste.

1. BACKGROUND

Shortage of land for waste disposal and inappropriate landfill site is one of the biggest problems in most of large urban areas in the world which has a big negative effect on the human, social, and environmental sound (Mcfaden, 2003). Therefore more efforts are needed to overcome this problem that leads different agencies and establishments to find common limitations to protect human and environment from these effects (Friedman, 1998).

The Environmental Protection Agency (1996) issued many regulations and limitation to control unfriendly environment projects, one of these is landfill site criteria, also many agencies in different countries of the developed world were established to control this process but in the third world countries just started to establish such agencies and institutions (Palestinian Agency for Environmental Affairs, 2006).

During the last decades it was a big difficulty to do such studies and in case of ability to

do that, it takes a lot of time and efforts, but nowadays it becomes easier by using GIS which gives a big ability and functionality to find the best location with many limitations. GIS has very distinguishing and powerful functions and can play an important role in decision making and planning process. “The most distinguishing parts of a GIS are its functions for spatial analysis, i.e. operators that use spatial data to derive new geoinformation. Spatial queries and process models play an important role in satisfying user needs. The combination of database, GIS software, rules, and reasoning mechanism (implemented as a so-called inference engine) leads to what is sometimes called a spatial decision support system (SDSS)”(Rolf, 2004).

2. STUDY SITE

Ramallah district is located in the middle part of the West Bank with a total area of 855 km² (Ezat, 2000). It occupies approximately 14.5% of the West Bank area. Currently only 4.35% of the District is inhabited by Palestinian built up area, while approximately 20.3% is occupied by either Israeli settlements, nature reserves or closed military areas (ARIJ, 1998).

The general topography of the West Bank is dominated by several mountain ridges forming a central ridge in a general north-south direction. In Ramallah District, the ridge rises to a height of 860 to 900 meters above sea level. The central ridge forms the main watershed of the region. The streams flowing from the central ridge are seasonable; their general direction being the Jordan River in the east, and the Mediterranean Sea in the west. Soil composition in the district area is mainly shallow layers of clay and silt with some chalk. The depth of these topsoil deposits usually does not exceed two meters (PHG, 2006).

The number of inhabitants in the District is about 284,960, in 15 municipalities and 53 village councils, 2 project committees and 5 refuge camps (PCBS, 1999). In Ramallah district a landfill site was established in the late 1960s, with an original area of about 4500 m². Although it was a random dumpsite, it was located far from urban areas. Burning the garbage was common so that the total accumulation of solid waste was limited. Since the early 1990s, however, the municipality stopped burning wastes as the built-up areas expanded toward the dumpsite and smoke and toxins spread over residential and industrial areas (Al-Khatib, 2003). As a result of that many studies that discussing the solid waste management situation in Ramallah district were conducted; Solid Waste Management in Emergency (Al-Humaidi, 1995): A Case Study concluded “The Israeli aggressions against the Palestinian infrastructure have affected all aspects of life for Palestinian civilians, including environmental conditions. The case of closing the largest landfill site of al-Bireh (a twin city of Ramallah), and imposing restrictions on finding a suitable alternative for the overloaded landfill of Ramallah is one example among many that demonstrates the deliberate targeting of the Palestinian infrastructure. This situation has resulted in the spread of garbage in the streets in addition to many randomly distributed dumpsites in residential areas, threatening the environmental health of the Palestinian population”.

As a result, the accumulation of wastes reached risky levels, with piles of more than 40 meters high. In 1995, the Ramallah municipality tried to close the dump and searched for an alternative. Choices were very limited in the overpopulated and confined city. The problem became more complicated when the nearby town of Beituniya closed its landfill, as this site was also located within the populated area which became harmful for public health, and began to use the Ramallah landfill in 1996 (Al-Khatib, 2003).

Al-Bireh city, adjacent to Ramallah city, had its own dumping site outside its boundaries

since 1981. The landfill is considered to be in area C (controlled by the Israeli military) that closed the landfill after the Second Intifada in 2002. After closing both landfills in Ramallah and Albireh, more than 100,000 people became without any available proper landfill. "This situation has resulted in the spread of garbage in the streets in addition to many randomly distributed dumpsites in residential areas " (Shahi, 2004).

Through the second Intifada (2000) the solid waste management in the West Bank became worse because solid waste can not be transported to reach dump sites outside municipal boundaries. As a result of that many vacant areas within city limits were used as dump site without taking any criteria into consideration. The major problems of this sector are: inefficient and inconsistent collection services in West Bank governorates, many illegal and random dumpsites were created, weak collection services, and consequently increased health problem (PCBS, 2001). Different types of solid waste are produced in Ramallah district like commercial, medical, agricultural, industrial, and domestic. The main one is the domestic solid waste; it forms more than 60% of the total solid waste while the other contributes with less than 40%. The solid waste generation in Ramallah district is estimated by 480 ton per day (Palestinian Ministry of Planning, 1998). In this research a landfill site was allocated to serve as a regional site for the District, using GIS applications and spatial analysis methodology.

3.METHODOLOGY

GIS is a powerful tool for decision making, "it is a tool for planning development and environmental degradation control as well as instrument for decision support system. It consists of georeferenced database, and on the other hand it has powerful techniques for data acquisition, actualization, processing and visualization of the results." (Stillwell, 2004).

In this paper, GIS plays a major role in determining the "best location" for a landfill site according to predefined criteria based on scientific standards and measurements. The aim is to avoid the need for impact mitigation and ongoing management by selecting a site where natural barriers protect environmental quality and where there will not be adverse impact on existing and future development" (EPA, 1996). To build a GIS model, the following layers were used (Fig.1):

Geological formation, rainfall, district boundary, built-up area, natural reserves, settlements, major roads, local roads, land use, springs, wells, ground water, I-map, P-map, soil type, and topography.

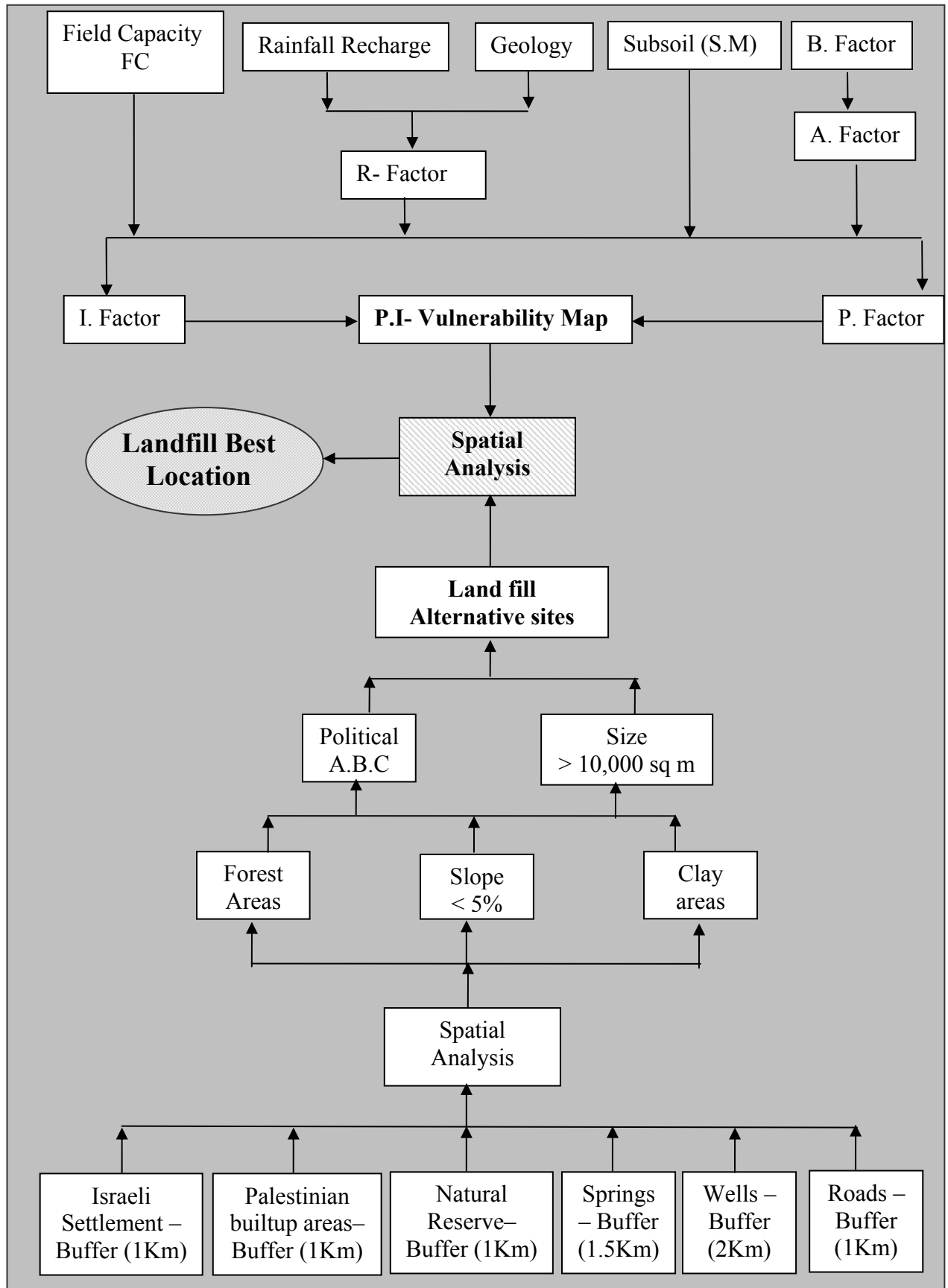


Figure 1: Methodology (layers prepared)

4.ANALYSIS

4.1-Groundwater Vulnerability:

The origin-pathway-target model was adopted in order to come up with vulnerability map for the study area by PI Method. The PI Method is based on an origin-pathway-target model: The origin of the assumed hazard is the ground surface; the groundwater table in the uppermost aquifer is the target; the pathway includes the layers between the ground surface and the groundwater surface (Adams, 1992). Thus, the PI method can be used for resource vulnerability mapping. However, if the resource vulnerability map is intersected with a map showing the flow route in the aquifer towards a spring or well, it can also be used for source vulnerability mapping. The acronym stands for the two factors protective cover (P) and infiltration conditions (I) (Adams, 1992).

P is divided into five classes. From $P = 1$ for a very low degree of protection to $P = 5$ for very thick and protective overlying layers. Where "**I**" describes the infiltration conditions, particularly the degree to which the protective cover is bypassed as a result of lateral surface and subsurface flow in the catchment's of swallow holes and sinking streams. The "**I**" factor is 1.0 if the infiltration occurs diffusely, e.g. on a flat, highly permeable and free draining surface. In contrast, the protective cover is completely bypassed by a swallow hole, through which surface water may pass directly into the karst aquifer the "**I**" factor is 0.0 in such a case. The catchment's of a sinking stream is assigned a value between 0.0 and 1.0, depending on the proportion of lateral flow components. The I map shows the spatial distribution of the I factor.

The final protection factor Π is the product of P and I. It is subdivided into five classes. A protective factor of $\Pi \leq 1$ indicates a very low degree of protection and an extreme vulnerability to contamination; $\Pi = 5$ indicates a high degree of protection and a very

low vulnerability.

The vulnerability map is obtained by intersecting the *P map* with the *I map*, where the *P* map shows the effectiveness of the productive cover as a function of the thickness and permeability of all the strata above the Groundwater surface, and the *I* map shows the degree to which the protective cover is bypassed.

4.2- GIS Procedure for landfill site allocation:

To get the proper site for landfill in Ramallah district from the base map, the following procedure was followed:

Step 1: Create vulnerability map:

$$PTS = [T + \{SM + \Sigma BM\} * R + A] \quad (1)$$

Pts = total protective function

T = Field Capacity for top soil

S = Grain size distribution for subsoil

M = Thickness of each stratum in [m]

B = Bedrock

R = Recharge

A = Artesian pressure

And so the following maps were created

- Apply the above equation to create the Pts map
- Apply the relation between Pts and P to create P map
- Multiply P map with I map to create the vulnerability map.

Other needed layers:

1. Field capacity for top soil 2.Rainfall recharge for Ramallah district 3.R-factor for geological formations 4. SM values for subsoil 5.Bedrock for geological formation 6. Sum of B*M

7. Artesian pressure

1- Field Capacity Map

Field Capacity (FC) is the ability of the top soil to store water, increasing field capacity means high capacity to store water. The table below (table 1) shows field capacity for soils found in the Ramallah District based on type of soil and effective field capacity (eFC), then map that shows the different values of field capacity according to soil type was created.

Types of soil	eFC (mm) up to 1m depth	Field Capacity (T)
Grumusols	460	750
Terra Rossa, Brown Rendzinas &Pale rendizinas	446	750
Brown Rendzinas &Pale rendizinas	334	750
Brown Lithosols &Loessial arid brown soils	140-200	250
Loessial serozems	140-200	250
Brown lithosols &Loessial serozems	90-140	125

Table 1: Field Capacity for soil found in the Ramallah District (Zwahlen, 2004)

2- Recharge Map

Recharge is the amount of rainfall that percolates through the land surface to arrive at the water table. The values of recharge have been calculated based on the equations below [8]:

$$r = 0.6 * (P - 285) \quad \text{for } P > 700 \text{ mm}$$

$$r = 0.46 * (P - 159) \quad \text{for } 700 > P > 456 \text{ mm}$$

$$r = 0.3 * (P) \quad \text{for } 456\text{mm} > P$$

Where r = Recharge from rainfall in mm/ year.

P = Annual rainfall in mm/year.

The Procedure to calculate Recharge-factor (R) is as follows:

1- Union between geology and rainfall maps to combine each geological formation in Ramallah District with its amount of rainfall (p), then the rainfall recharge (r) was calculated based on above equations (Table. 2).

2- Determine the R-factor based on cost Action 620 method (Zwahlen, 2004).

Formation	Recharge[mm/y]	R-factor
Lower cenomaniac	7	1.75
Upper cenomaniac	226	1.25
Turonian	105	1.5
Senonian	7	1.75
Albian	135	1.5
Quaternary	11	1.75
Lower cretaceous	11	1.75
Eocene	180	1.5

Table 2: R-factor for geological formation in Ramallah District

3- Subsoil

The subsoil is the soil layer that lies below the top soil, it consists of gravel, sand, silt, and clay. Grain size distribution can be used as a means to evaluate the protective function of the subsoil as shown in (Table. 3).

Types of soil	Type of subsoil "grain size distribution "	S(value)	Thickness of soil (M)	S*M
Grumusols	Clay	500	1.0	500
Terra Rossa, Brown Rendzinas &Pale rendizinas	Clayey loam	400	0.5	200
Brown Rendzinas &Pale rendizinas	Clay	500	1.5	750
Brown Lithosols &Loessial arid brown soils	Slitly clayey sand	75	0.5	37.5
Loessial serozems	loamy	400	1.5	600
Brown lithosols &Loessial serozems	Sility clay	320	1.0	320

Table 3: SM values for subsoil (PHG, 2006).

4- Lithology and Fracturing

The lithology (L) is the physical makeup, including the mineral composition, grain size, and grain packing, of the sediments or rocks that make up the geological system. While fracture (F) is a natural phenomenon occurs in rocks and causes separation into pieces under the action of stress. However the bedrock (B) is the multiplication between two factors lithology and fracturing see Table (4).

Formation	lithology	L	F	B = L*F
Quaternary	Nari (surface crust) and alluvium gravels and fan deposits	5	4.0	20
Miocene	Conglomerates, Marl, chalk	5	20	100
Eocene	Reefal limestone	5	0.5	1.5
Senonian	Marl, chalk , chert	20	25.0	500
Turonian	White limestone	5	0.5	1.5
Upper cenomainan	Karstic Dolomite	5	0.3	1.5
Upper cenomainan	Limestone and dolostone	5	0.3	1.5
Albian	Reefal limestone	5	0.3	1.5

Table 4: Lithology and Fracturing for geological formation (PHG, 2006).

The depth which the pollutants pass in order to reach groundwater is **M**, and can be obtained from two maps (water level and topography map). Also it can be calculated from this equation:

$$M = E - W \quad (2)$$

Where: E is the elevation for formation

W is the water table above sea level.

Procedure followed to calculate BM factor:

- union between water table and topography maps.
- Calculating the depth M to groundwater level based on equation (2).

- Determining typical thickness m for each geological formation due to their appearance to surface as shown in Table (5) by using stratigraphical section for the West Bank.

F	b1	b2	b3	b4	b5	b6	b7	b8	m1	m2	m3	m4	m5	m6	m7
Q 1	20	1.5	500	1.5	1.5	100	20	1.5	155	380	278	115	330	330	497
E 2	20	1.5	500	1.5	1.5	100	20	1.5	0	380	278	115	330	330	497
S 3	20	1.5	500	1.5	1.5	100	20	1.5	0	0	278	115	330	330	497
T4	20	1.5	500	1.5	1.5	100	20	1.5	0	0	0	115	330	330	497
U.C 5	20	1.5	500	1.5	1.5	100	20	1.5	0	0	0	115	330	330	497
Y (e) 6	20	1.5	500	1.5	1.5	100	20	1.5	0	0	0	0	330	330	497
Y(w) 7	20	1.5	500	1.5	1.5	100	20	1.5	0	0	0	0	0	330	497
A 8	20	1.5	500	1.5	1.5	100	20	1.5	0	0	0	0	0	0	497

Table 5: bedrock values and typical thickness for geological formations

Where:

b: bedrock. **m**: thickness for each formation. **Q**: Quaternary. **E**: Eocene . **S**: Senonian.

T: Turonian. **U.C**: Upper cenomianan. **Y (e)**: yata lower cenomianan, east. **Y (w)**: yata

lower cenomianan, weat. **A** : Albian.

After determining m , and b for each geologic formation, the following equation was applied to find the sum of bedrock multiplied by groundwater thickness.

$$\Sigma BM = \Sigma b_{imi} \quad (3)$$

5- Artesian pressure

The artesian pressure of the geologic formation depends on the type of aquifer for that formation, i.e. confined or unconfined. The confined aquifers occur where groundwater is confined under pressure greater than atmospheric by overlying relatively impermeable strata. While unconfined aquifer is one in which a water table varies in undulating form and in slope, depending on areas of recharge and discharge, pump age from wells and permeability as shown in Table (6).

Formation	Type	A-value
Lower cenomainan	Confined	1500
Upper cenomainan	unconfined	0
Turonian	unconfined	0
Senonian	unconfined	0
	Confined	1500
Quaternary	unconfined	0
Lower cretaceous	Confined	1500
Eocene	unconfined	0

Table 6: Types of Formation in Ramallah District based on Zwahlen (2004).

P-map

The total protective function (PTS) was calculated according to equation (1), then the p-factor was constructed according to cost action 620 method (Zwahlen, 2004) as follows:

for PTS between (1000-10000) that means it has high protective cover and has P -factor value 4 while the other classification was larger than (10000) which means that it has a very high protective cover and has P -factor value 5 and when PTS has value less than 1000 , it gives P a value of 3.

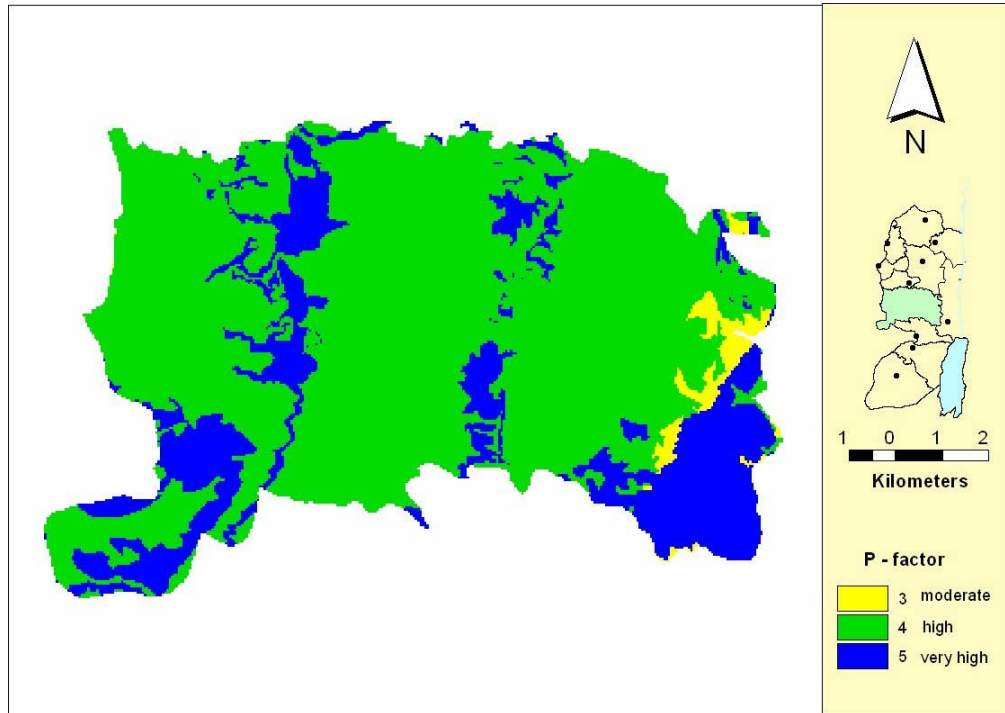


Figure 2: Protective cover map (P map)

I -map

I factor express the degree to which protective cover is bypassed by lateral surface and subsurface flow the spatial distribution of I factor was shown on **I map** (PHG, 2006).

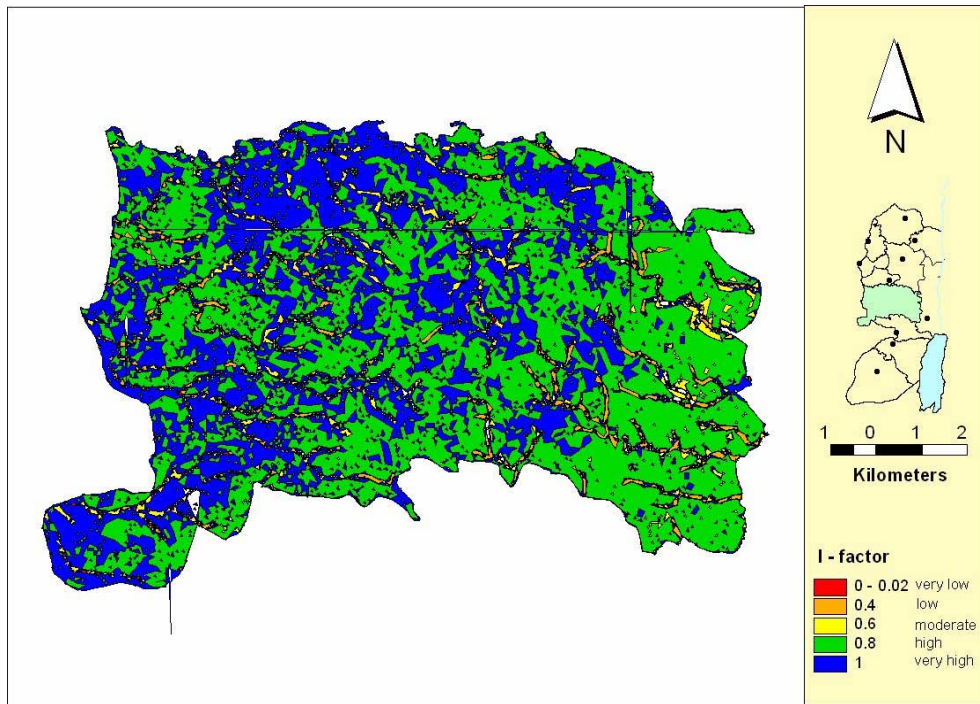


Figure 3: I map for Ramallah district.

Vulnerability map

Finally Vulnerability map was obtained by making a union between I map and P map which shows the intrinsic vulnerability and the natural protection of the upper aquifers. PI factors ranges between 0.0 (high Vulnerability) and 5.0 (low Vulnerability) as shown in (Fig. 4).

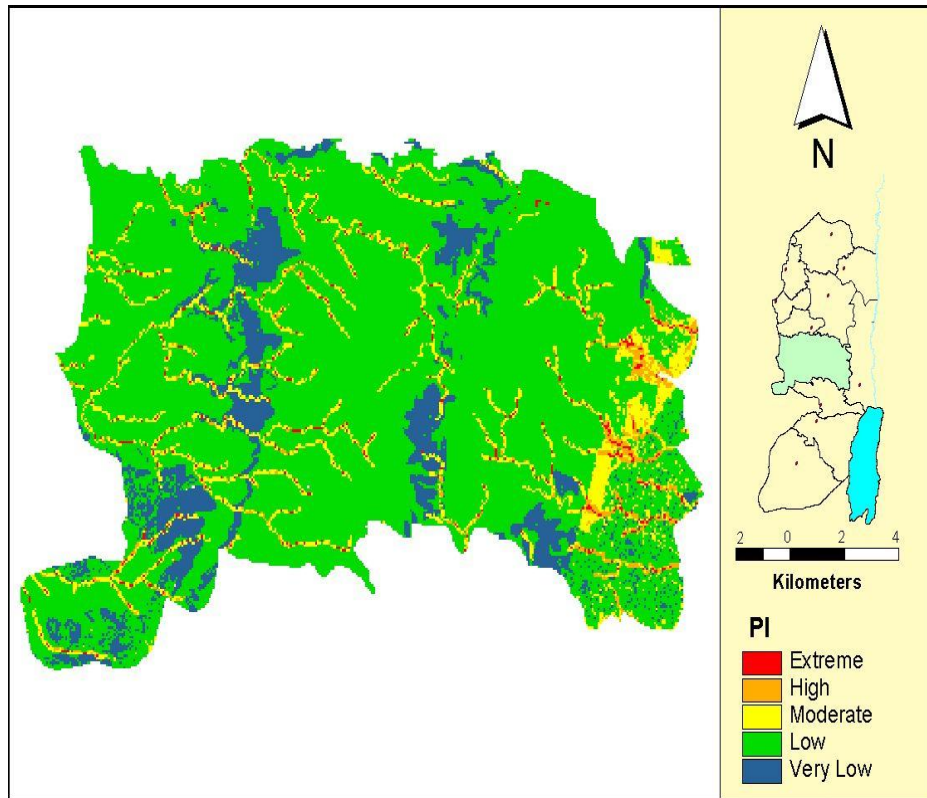


Figure 4: Vulnerability map for Ramallah District

4.3- Available areas by Buffer Zones

To find the excluded areas based on the criteria listed in (fig.1), the following buffer zones were created.

1- Israeli settlement

The landfill site is prevented to be located within 1 km from the Israeli settlements; a 1 km buffer around the Israeli settlement was created. So the available area excluded buffer zone around Israeli settlements was calculated by subtracting it from the whole area of Ramallah district.

2- Built up area

The landfill site is prevented to be located within 1 km from the any built up areas, a 1 km buffer around the built up area was created. So the available area excluded buffer zone around Palestinian built up areas was calculated by subtracting it from the whole area of

Ramallah district.

3-Natural reserves

The landfill site is prevented to be located within 1 km from natural reserves; a 1 km buffer around natural reserves was created. So the available area excluded buffer zone around natural reserves areas was calculated by subtracting it from the whole area of Ramallah district.

4- Springs

The landfill site is prevented to be located within 1.5 km from the springs; a 1.5 km buffer around springs was created. So the available area excluded buffer zone around springs was calculated by subtracting it from the whole area of Ramallah district.

5- Wells

The landfill site is prevented to be located within 2 km from the wells; a 2 km buffer around wells was created. So the available area excluded buffer zone around wells areas was calculated by subtracting it from the whole area of Ramallah district

Available areas by area characteristics

In this step a query was done to find the areas that meet the following conditions based on criteria adopted by Palestinian Agency for Environmental Affairs (2006) for best location of landfill as shown in (fig. 1):

Area should meet the following criteria:

- Land use = forest
- Soil type = clay
- Slope < 5%

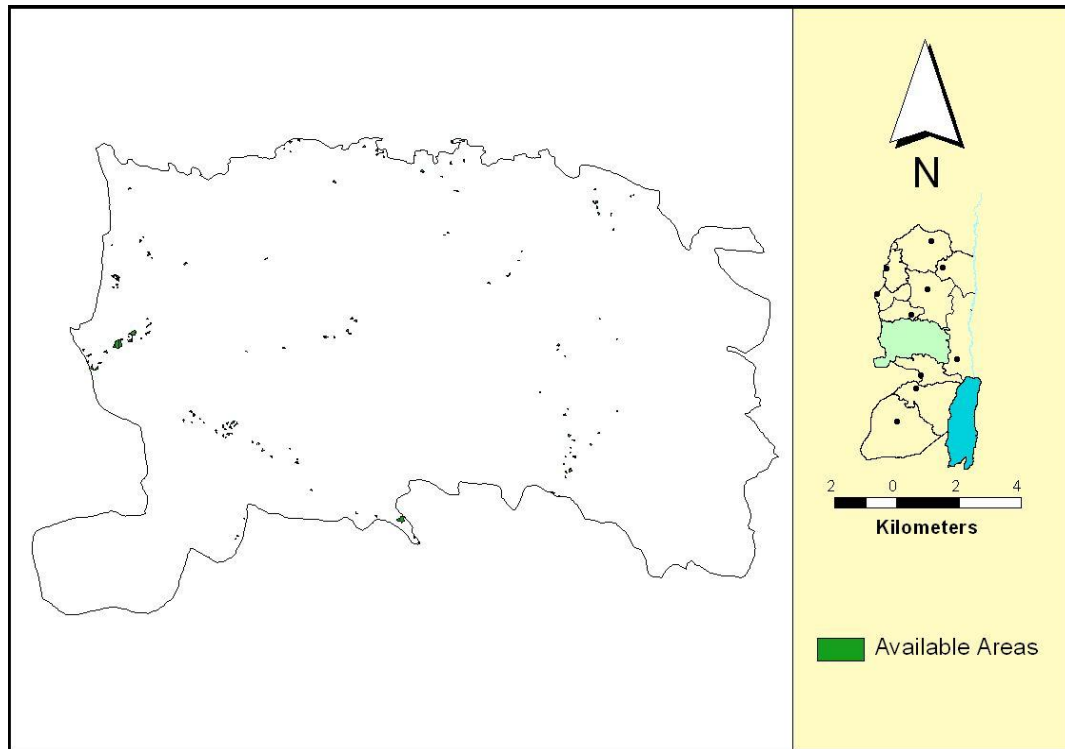


Figure 5: available areas for landfill site.

Landfill Alternatives

To find the best location for a landfill site in Ramallah district, two criteria were formulated, the first is the area needed to construct a landfill site as estimated by Ramallah municipality, the needed area for landfill site should be at least 10 donums (10,000 m²), so a query was done to allocate the available area for landfill with an area of 10 donums or more.

<i>Area_dunms</i>	<i>Type</i>	<i>Type</i>	<i>Where</i>
17.71087371970	Forest	Area C	WestBank
17.71087371970	Forest	Area C	WestBank
10.22531045470	Forest	Area B	WestBank
87.41459016010	Forest	Area C	WestBank
64.86951388440	Forest	Area C	WestBank
64.86951388440	Forest	Area C	WestBank
12.04780989760	Forest	Area C	WestBank
48.02683899690	Forest	Area C	WestBank
92.44736385490	Forest	Area C	WestBank
16.86554157230	Forest	Area C	WestBank
11.13510197640	Forest	Area C	WestBank

able 7: available areas for landfill site with area > 10 donums.

The second is the political aspects based on (A,B, and C regions);

According to Oslo agreement between Palestinian and Israelis, West Bank and Gaza were divided into three areas A, B, and C areas. ‘A’ areas, controlled by the Palestinian Authority (PA), are mostly urbanized and not suitable for landfills. ‘B’ areas are administratively operated by the PA, but militarily controlled by the Israelis. ‘C’ areas are less urbanized, far from populated areas, and would be potentially adequate for constructing new landfill site but they are fully controlled by Israelis and so landfill construction in theses areas are restricted. So the landfill site should be places in area "B".

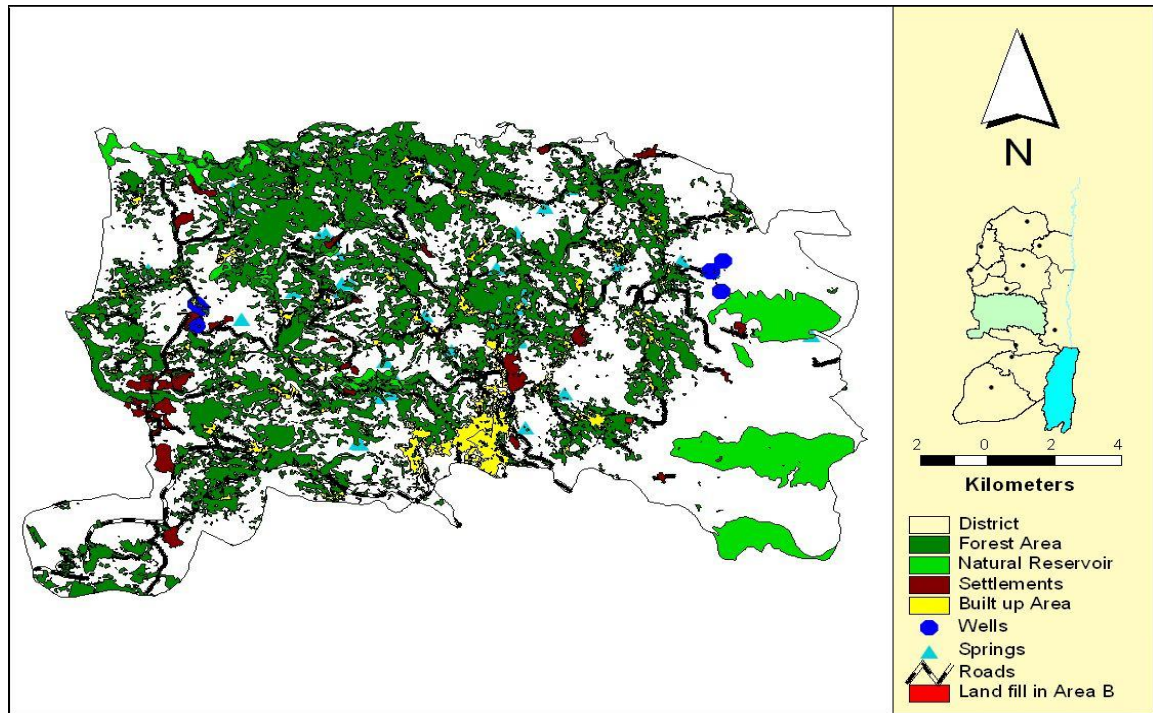


Figure 6: Landfill location alternatives in Ramallah district

The result was shown for the landfill alternatives (fig. 6), a spatial analysis was conducted to delineate these alternative sites to the lands of low to very low vulnerability.

A query was done to find available landfill sites that are located in B areas. The result was a site with an area of 10.2 donums which is located near Dir-Dibwan village (30 km from Ramallah city).

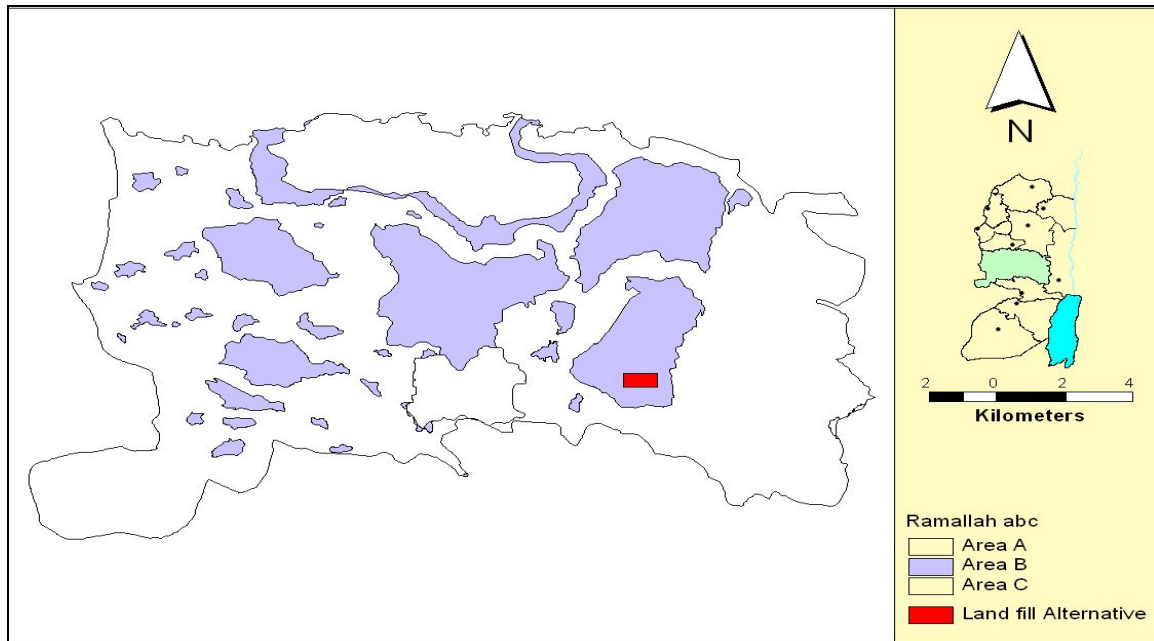


Figure 7: Best location for a landfill in Ramallah district.

5.CONCLUSION

GIS could effectively be used as a management and an analysis tool that facilitates planning process. In this research, GIS software was used to locate the best landfill site for Ramallah district by creating maps according to scientific criteria and standards. Hence, it's worthy to recommend the application of this tool in different planning aspects and fields.

As discussed in the methodology flow charts and tables, more than thirty maps were created by using GIS analysis for Ramallah district. The research depended on two components: one is the vulnerability map which revealed the areas of less threat on nature. The other is the buffer areas around sensitive spots and lines in order to find the best location for the landfill site taking wells, springs, natural reserves, springs, road network into consideration. Then by superimposing these two thematic maps the result was the best location for a landfill site taking all the mentioned criteria and standards into consideration.

The selected site located in areas with low to very low vulnerability which gives a high ability to prevent leachate comes from waste to reach ground water. Also the site is located in clayey area that has less permeability, with a slope less than 5% that will prevent any pollutant to be mixed with drainage water.

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